Agricultures
et défis du monde
Collection Cirad-AFD

The agroecological transition of agricultural systems in the Global South

F.-X. Côte, E. Poirier-Magona,
S. Perret, P. Roudier,
B. Rapidel, M.-C. Thirion,
éditors

éditions Quæ

Chapter 13

Agroecology and climate change: close links which give cause for hope

Emmanuel Torquebiau, Philippe Roudier, Julien Demenois, Stéphane Saj, Étienne Hainzelin, Florent Maraux

Agriculture is undoubtedly one of the most climate-dependent human activities. Every farmer watches the sky and takes weather conditions (rainfall, temperature, wind, etc.) into account in his agricultural activities. Agriculture's industrial version, which is almost the only form now found in developed countries, has however tried to overcome this dependence. Instead of adapting to environmental and climatic constraints and their variability, this form of agriculture, based on economies of scale, often seeks to modify the environment, for example by irrigating, standardizing the topography, increasing plot size and reducing landscape heterogeneity. The aim is to ensure that high-yield varieties selected for a standard environment find optimum growth conditions at all costs. This approach, which is based on the assumption that it is always possible to control cultivation conditions, finds itself confronting a new factor that has emerged in recent years: climate change.

The relationship between agriculture and climate change

There are several examples of the impact of climate change on agriculture: irregular seasonality, precipitation that is shifted in time or distributed differently, extreme events, temperature changes that advance or delay harvest dates, more active pests, etc. The impacts are varied and also affect yields (Roudier *et al.*, 2011) as well as the nutritional quality of harvested products. Indeed, Myers *et al.* (2014) predict a significant reduction in protein, zinc and iron content in wheat and rice due to an increase in the concentration of atmospheric carbon. In countries of the Global South, climate change impacts the agricultural sector particularly severely because of the high dependence of agriculture on the environment (for example, the vast majority of African agricultural land is unirrigated), which makes it more vulnerable, and because economic conditions do not allow intensive farming to be adopted. In their Nationally Determined Contributions (NDCs), presented by the world's countries in the Paris Agreement of 2015 (COP 21), all sub-Saharan African countries mentioned the agricultural sector among the options selected for adaptation to climate change.

However, the agricultural sector does not just suffer from the impacts of climate change; it is also partially answerable for it. This sector is a massive emitter of greenhouse gases, responsible for about 12% of anthropogenic emissions of these gases, and up to 24% if emissions from land-use changes are included, i.e. essentially tropical deforestation (IPCC, 2014). But there is now a serious effort to understand how agriculture (and more broadly land use, including forestry) can be one of the solutions to climate change because of the potential for carbon sequestration in soils and vegetation and because of the possible reduction of agricultural emissions through the modification of a number of practices such as the large-scale use of synthetic fertilizers. However, it is important to distinguish the increase in the stock of organic carbon in the soil from its sequestration; only the latter corresponds to a withdrawal of carbon dioxide from the atmosphere (Chenu *et al.*, 2018). The concept of 'climate-smart agriculture' tries to take into account the fact that agriculture can be an aggravating factor of climate change, but which at the same time suffers strongly from its consequences. Climate-smart agriculture attempts to respond simultaneously to three issues:
– adapting to climate change (a function sometimes equated – wrongly – to resilience, which is a broader concept that also includes risk reduction);
– mitigating climate change;
– ensuring food security in a sustainable way.

Recent analyses have shown the complementarity that exists between agroecology and climate-smart agriculture, and in particular that the latter would have everything to gain by integrating concepts of the former (Saj *et al.*, 2017).

Agroecology, an integrated solution combining climate change adaptation and mitigation

The principles of agroecology

In its biophysical dimension, agroecology is based on the principles of diversity, efficient use of natural resources, nutrient recycling, natural regulation of and synergy between the different components of agroecosystems, which are most often multi-specific. These principles make it possible to help implement agricultural practices adapted and resilient to climate change. While the concept of resilience has several definitions, we understand it here as the ability of a system to cope with a series of shocks and stresses, in a dynamic and uncertain context.

Resilience is characterized by three capabilities of a system:
– absorption and recovery;
– preparation;
– transformation.

The diversity of agroecological practices helps strengthen each of these three capabilities and thus improves the system's resilience to future climate change. For example, water conservation techniques allow crops to cope better with an unexpected rainfall deficit (absorption); the varietal diversity available to the farmer allows him to choose, before the cultivation season, the optimal varieties to plant (by anticipating medium-term variations); the diversity of varieties and crops and their coupling with livestock husbandry equips an agrosystem with a transformative capacity that allows it to survive long-term major changes such as those modelled by climate change scenarios. Figure 13.1 shows how traditional varieties of millet and sorghum will be less impacted by a +4°C temperature increase scenario than some improved varieties (Roudier, 2012). Agroecology is a viable option to improve the adaptation and resilience of agriculture to climate change because of its inherent characteristics: the diversification of crops and plots, landscape heterogeneity, the use of biodiversity and agrobiodiversity (diversity of useful plants and animals), reduction in use of greenhouse gas emitting inputs, biological pest control, symbioses and various interactions (rhizobia, mycorrhizae, push-pull[1]), etc.

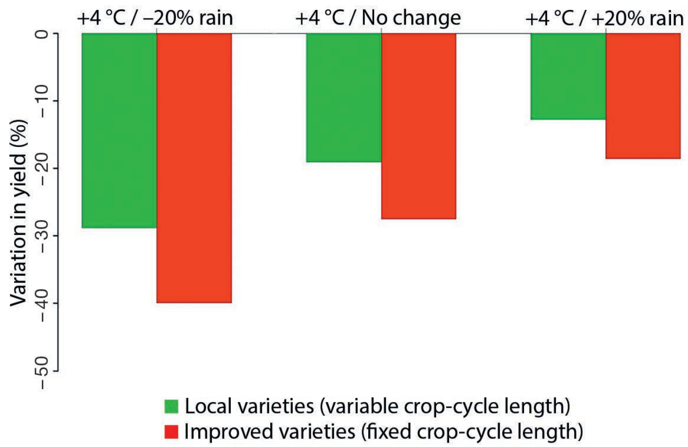

Figure 13.1. Mean yield variations of millet and sorghum in West Africa (35 stations) for local varieties and improved varieties under three scenarios of future climate change (taking the 1961-1990 period as reference). These results are simulations derived from the Sarra-H model (for the methodology, see Roudier, 2012).

Climate risk

Climate risk results from a combination of hazards and vulnerabilities (Gilard, 2015). Vulnerability to climate change depends on exposure to hazards whose probability may vary, as well as the sensitivity and adaptability of the societies concerned. While adaptation can reduce sensitivity to climate change, it is mitigation that can reduce hazards, i.e. exposure to these changes. However, adaptation is localized, while mitigation only works on a global scale, with its effects acting on the atmosphere shared by all. Thanks to its proven properties of enhancing capacities of adaptation, agroecology can have a moderating effect on climate risk and vulnerability. Reducing vulnerability through individual or collective agroecological innovations will often prove to be more effective and no doubt less expensive than reducing hazards through complex technical interventions. In the face of an expected rainfall vulnerability, the spatial and temporal diversification of crops at the landscape scale can, for example, be more effective than the construction of large irrigation structures.

1. See chapter 11.

Mitigating climate change

Mitigation of climate change by reducing greenhouse gas emissions or by carbon sequestration is not an explicit goal of agroecology. Although it can be assumed that in many cases agroecology allows for increased sequestration and lower emissions due to reduced use of synthetic inputs, the precise quantitative comparison in this domain between conventional agriculture and agroecology remains to be done. While there are no regulatory requirements or formal certifications for agroecology, its characteristics nevertheless contribute to mitigating climate change, for example by increasing the total biomass of cultivated plots or by providing soil coverage throughout the year through increased accumulation of organic matter (and therefore of carbon) in the soil. Several cases highlighting the simultaneous potentials of agroecology for climate change adaptation and mitigation have been described in the literature (for example, Altieri *et al.*, 2015; 2017; Paustian *et al.*, 1998) for instance in agroforestry (Photo 13.1), intercropping practices (Photo 13.2), or large-scale heterogeneity maintained in multifunctional landscapes (Photo 13.3). This observation has made it possible to say that while climate-smart agriculture is not necessarily agroecological, agroecology is necessarily climate-smart (Tittonell, 2015).

Agroecology contributes most to mitigating climate change through soil carbon sequestration. This function has been formalized by a recent initiative called '4 per 1000: Soils for food security and climate' (4 per 1000, 2018; Soussana *et al.*, 2018), whose threefold objective is:
– mitigating climate change;
– adapting agriculture to climate change;
– advancing food security.

Agricultural and forest soils contain two to three times more carbon than does the atmosphere, especially in the form of organic matter. Thus, it is estimated that an increase in the organic carbon stock of upper soil horizons at an annual rate of 4 per 1000 could be able to offset annual anthropogenic emissions of greenhouse gases, provided greenhouse gas emissions from deforestation and forest degradation are reduced at the same time. This objective is technically feasible (Soussana *et al.*, 2018) and is a 'no regret' option because an increase in the organic carbon content of soils also increases their fertility, decreases their sensitivity to erosion and increases their water retention capacity. Cases of carbon sequestration in tropical areas at rates equal to or greater than 4 per 1000 per year have been described, for example, through the use of compost or of incorporation of crop residues into the soil (Kenne *et al.*, 2016), in agroforestry (D'Andouss Kissi *et al.*, 2013) and in conservation agriculture (Corbeels *et al.*, 2018).

Positive agroecological feedback

The most promising approach of using agroecology to combat climate change is to look for systems that favour adaptation and mitigation at the same time. This is sometimes referred to as mitigation-adaptation co-benefits or synergy but can be best described as positive feedback between adaptation and mitigation. Adaptation can lead to positive feedback on mitigation, for example, when innovative practices

Photo 13.1. Cocoa trees and fruit trees in an agroforest, Ghana. © E. Torquebiau/CIRAD.

Photo 13.2. Intercropping (maize and beans), Kenya. © E. Torquebiau/CIRAD.

Photo 13.3. Multifunctional landscape (land sharing) with rivers, hedges, fruit trees, human habitation and agroforest, Sumatra, Indonesia. © E. Torquebiau/CIRAD.

designed to improve soil fertility lead to an increase in soil organic matter and thus a reduction in nitrous oxide emissions (N_2O) due to reduced use of synthetic fertilizers. This effect is proven, for example, in the case of agroforestry coffee plantations: even if there is more nitrogen in an agroforestry coffee plantation than in a full-sun one (and therefore potentially more N_2O emissions), its total carbon footprint is lower (Hergoualc'h *et al.*, 2012). In a similar way, mitigation can lead to a positive feedback on adaptation when an objective of increasing soil carbon sequestration results in benefits in terms of soil properties and improved stress resilience, with positive consequences for agricultural production.

Agroforestry provides many examples of positive agroecological feedbacks, such as the one known as 'the regreening of the Sahel' in Niger (Photo 13.4). The practice is based on the assisted natural regeneration of trees in cultivated fields, an old method which was slowly dying out but which innovative public policies (the transfer from the State to farmers of property rights over trees) helped revive (Sendzimir *et al.*, 2011). Tree density has increased dramatically, improving soil fertility and the microclimate (adaptation), favouring aboveground and underground biomass and hence carbon storage (mitigation), all of which is having a positive impact on farmer incomes and food security. Another agroforestry example is the shading of cocoa trees or coffee plants by 'shade' trees, a practice that helps offset losses due to possible increases in temperatures. Agriculture in the Global South provides compelling examples that can be extended to the entire planet.

Photo 13.4. Agroforestry intercropping of maize and *Faidherbia albida*, Dolekaha, Côte d'Ivoire. © Dominique Louppe/CIRAD.

Many other agroecological options can promote adaptation-mitigation synergies: conservation agriculture, intercropping, organic fertilizers, improved pasture management, water management, no-till practices, permanent soil cover, etc. Even livestock husbandry, often blamed for the emission of large amounts of greenhouse gases, can, depending on how pastures are managed and used, contribute to this balance between adaptation and mitigation. In Senegal, a study of extensive livestock farming at the territorial level, a practice that is especially adapted to local conditions, shows that, over annual time steps, greenhouse gas emissions and carbon sequestration balance each other out (Vayssières *et al.*, 2017).

It is indeed only on a scale exceeding the plot, or even the farm, that many approaches can claim to promote the synergy between adaptation and mitigation. In multifunctional landscapes (Torquebiau, 2015; Denier *et al.*, 2015), it is possible to combine objectives of agricultural or forestry production with objectives of nature and biodiversity protection. This concept, known as 'land sharing' (Grau *et al.*, 2013), assigns adaptation or mitigation objectives to neighbouring and often interacting landscape units. It is in direct opposition to the concept of 'land sparing' in which agricultural production and nature protection are spatially separated. Land sparing is a corollary of the Green Revolution and the well-known 'Borlaug hypothesis': maximizing production in agricultural areas with productive varieties, irrigation and inputs in order to protect nature elsewhere. The continued expansion of agricultural lands at the expense of natural environments has proven this hypothesis false. In contrast, land sharing is essentially agroecological and promotes 'climate-smart' landscapes (Harvey *et al.*, 2014; Torquebiau, 2017).

Box 13.1. Agrobiodiversity: a common good for increasing resilience to climate change

E. Torquebiau, P. Roudier, J. Demenois, S. Saj, É. Hainzelin, F. Maraux

The biodiversity of cultivated ecosystems – especially when it is useful for people, including in natural environments – is what is called agrobiodiversity. It forms the foundation of our agriculture but we have forgotten it over time; our agriculture today is based on too few species and a limited number of varieties within these species. Yet agrobiodiversity is an essential lever of agroecology (Hainzelin, 2013) because it is on the basis of this genetic, specific and landscape diversity that it is possible to design new farming systems that are more resilient to environmental and climatic hazards. It is through innovative breeding approaches and diversified farming practices, based on a wide range of species and species interactions, that it will be possible to respond to shifts in climatic and agroecological zones, the emergence of new pests and diseases, and increasingly frequent extreme climatic events. The agricultural and forestry systems that will contribute to mitigating climate change through carbon sequestration are those that are rich in biodiversity and biomass. It is 'perennial' farming (Perfecto *et al.*, 2009) that must be encouraged, based on the use of woody plants, cover crops, roots and tubers, or perennial grasses. The more widespread adoption of these practices, which have historically been used to respond to existing climatic hazards (choosing the variety depending on weather forecasts, for example), is being prevented today in several regions due to the reduced diversity of varieties available to farmers (Maikhuri *et al.*, 1997) as well as the emergence of patents for seeds, which were previously managed as a public good (Brush, 2005).

Prospects and limitations

Although agroecology is a concept that has existed for several decades (Wezel and Soldat, 2009), it is currently used only in the case of traditional agriculture and has not yet been widely disseminated. Even though the constraints imposed by climate change are certainly unwelcome, they can provide an opportunity to accelerate the spread of agroecology. A lack of support from official educational and research institutions may also partly explain this delay. In the past, agroecology has not been included – and often is not so even today – in agricultural education. The lack of reference to agroecology in the majority of public policies must also be blamed. Will the (delayed) inclusion of agriculture by the official bodies of the United Nations Framework Convention on Climate Change (UNFCCC) after COP 23 (November 2017) lead to changes in orientations? Given that agroecology has also been the focus of some development policies for some time (for example, at the FAO with its Symposium on Agroecology for Food Security and Nutrition; FAO, 2015; FAO Symposium, 2018), one can expect the agroecology and climate change themes to build one on the other.

The 'scaling up' of these potentially close links between agroecology and climate change remains a challenge. There is a great need to raise the awareness of farmers in the Global North as in the Global South to the fact that agroecology can represent a solution to the constraints of climate change. But how can we effectively go beyond successful experiments in a few locations to spread this scientific message to the greatest number of farmers when national public policies ignore agroecology or even contradict it with subsidies or various incentives for industrial agriculture? How to raise awareness of these innovative techniques when the staff of services providing technical support to farmers is itself trained in conventional agriculture? While we can now, especially because of the recent work on soil carbon (Soussana *et al.*, 2018), consider using agriculture as a contributory solution to climate change, it is only the forms of agriculture that embrace principles of agroecology that can really play this role.

It is also worth noting that agroecology runs counter to the interests of powerful actors (e.g. inputs suppliers) and therefore the mobilization of political will cannot be taken for granted. While the transition to agroecology can involve all types of agricultural structures, it is particularly well suited to small farms. Indeed, since they are based on the diversification of production and on the ecosystem's biological regulatory mechanisms, agroecological farming systems are inherently less demanding in terms of capital, and enjoy a high agri-environmental and socio-economic sustainability. Such analyses can inform future advocacy efforts essential to the formulation of public policies in the Global North as in the Global South. Finally, agroecology is fundamentally tied to the local context and its large-scale application depends on the dynamism of local innovation systems, not only at the level of agricultural practices but also at the level of commodity chains, and in relation to new links between urban and rural areas. This poses a huge challenge in terms of training and development of skills and redefines the role that the research community must play.

Thanks to its twofold action on climate change, agroecology can help nations meet their Nationally Determined Contributions (NDCs) presented by all the countries of the world at the time of the Paris Agreement in 2015 (COP 21) and which must be revised upwards by 2020. Worldwide, 89% of the countries refer in their contribution to the agricultural sector and the use of land in the broad sense (LULUCF: Land Use, Land Use Change and Forestry). More specifically, 78% of countries include agriculture in their mitigation options and 100% of sub-Saharan African countries cite it as an adaptation option (FAO, 2016). Agroecology is unfortunately mentioned explicitly only very rarely (Rwanda, Honduras) but some of its components do find inclusion: conservatory water management, improved pastoralism, agroecological fish farming, landscape approach, biological corridors, 'low carbon' farming practices, etc. Agroecology can therefore be a path to follow in order to meet national climate objectives.

References

4 per 1000, 2018. The 4 per 1000 Initiative. Soils for Food Security and Climate, http://4p1000.org.

Altieri M.A., Nicholls C.I., 2017. The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change*, 140 (1), 33-45.

Altieri M.A., Nicholls C.I., Henao A., Lana M.A., 2015. Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development*, 35 (3), 869-890.

Brush S.B., 2005. Protecting traditional agricultural knowledge, 17 Wash. U. J. L. & Pol'y 59 , http://openscholarship.wustl.edu/law_journal_law_policy/vol17/iss1/5 (retrieved 29 December 2018).

Chenu C., Angers D.A., Barré P., Derrien D., Arrouays D., Balesdent J., 2018. Increasing organic stocks in agricultural soils: Knowledge gaps and potential innovations. *Soil and Tillage Research*, https://doi.org/10.1016/j.still.2018.04.011.

Corbeels M., Naudin K., Guibert H., Torquebiau E., Cardinael R., 2018. The 4 per 1000 goal and soil carbon storage under agroforestry and conservation agriculture systems in sub-Saharan Africa. *Soil and Tillage Research*, https://doi.org/10.1016/j.still.2018.02.015.

D'Andous Kissi O., Guibert H., Palou Madi O., Ntoupka M., Deleporte P., Smektala G., Peltier R., 2013. Le bois, un atout pour la diffusion des plantations d'acacias gommiers au nord du Cameroun. *Revue forestière française*, 3, 241-253.

Denier L., Sherr S., Shames S., Chatterton P., Hovani L., Stam N., 2015. The Little Sustainable Landscapes Book: Achieving sustainable development through integrated landscape management, Global Canopy Programme, Oxford, United Kingdom, 158 p.

FAO, 2015. *Proceedings of the International Symposium on Agroecology for Food Security and Nutrition*, 18-19 September 2014, FAO, Rome, Italy, 426 p.

FAO, 2016. The Agriculture sectors in the Intended Nationally Determined Contributions: Summary, Environment and Natural Resources Management, Working paper #61.

FAO Symposium, 2018. 2nd International Symposium on Agroecology: Scaling Up agroecology to achieve the Sustainable Development Goals (SDGs). http://www.fao.org/about/meetings/second-international-agroecology-symposium/en/ (retrieved 22 January 2019).

Gilard O., 2015. Aléa, vulnérabilité et risque. *In*: *Changement climatique et agricultures du monde* (E. Torquebiau, ed.), Quæ, 27-36.

Grau R., Kuemmerle T., Macchi L., 2013. Beyond "land sparing versus land sharing": Environmental heterogeneity, globalization and the balance between agricultural production and nature conservation. Current Opinion in Environmental Sustainability, 5, 477-483.

Hainzelin E., ed., 2013. *Cultivating Biodiversity to Transform Agriculture*, CIRAD/Quæ/Springer Netherlands, Dordrecht, 261 p.

Harvey C.A., Chacón M., Donatti C.I., Garen E., Hannah L., Andrade A., Bede L., Brown D., Calle A., Chara J., Clement Ch., Gray E., Minh H.H., Minang P., Rodrıguez A.M., Seeberg-Elverfeldt Ch., Semroc B., Shames S., Smukler S., Somarriba E., Torquebiau E., Van Etten J., Wollenberg E., 2014. Climate-smart landscapes: Opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. *Conservation Letters*, 7 (2), 77-90, https://doi.org/10.1111/conl.12066.

Hergoualc'h K., Blanchart E., Skiba U., Hénault C., Harmand J.M., 2012. Changes in carbon stock and greenhouse gas balance in a coffee (*Coffea arabica*) monoculture versus an agroforestry system with *Inga densiflora*, in Costa Rica. *Agriculture, Ecosystems, Environment*, 148, 102-110.

IPCC, 2014. Summary for Policymakers. *In*: *Climate Change 2014: Mitigation of Climate Change*, contribution of Working Group III to the 5th Assessment Report of the Intergovernmental Panel on Climate Change (O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, J.C. Minx, eds), Cambridge University Press, Cambridge/New York, United Kingdom/United States, 33 p.

Kenne Kueteyim P., Guibert H., Kouassi Bredoumy S., 2016. Organic amendments do not reverse the decay of stock of carbon of tropical soils after setting the crops: Experiments in Ivory Coast and Benin, Conference EcoSummit, 29 August – 1 September 2016, Montpellier, France, Elsevier, Amsterdam, The Netherlands, 1 p.

Maikhuri R.K., Semwal R.L., Rao K.S., Nautiyal S., Saxena K.G., 1997. Eroding traditional crop diversity imperils the sustainability of agricultural systems in Central Himalaya. *Current Science*, 73 (9), 777-782.

Myers S., Zanobetti A., Kloog I., Huybers P., Leakey A.D.B., Bloom A.J., Carlisle E., Dietterich L.H., Fitzgerald G., Hasegawa T., Holbrook N.M., Nelson R.L., Ottman M.J., Raboy V., Sakai H., Sartor K.A., Schwartz J., Seneweera S., Tausz M., Usui Y., 2014. Increasing CO_2 threatens human nutrition. *Nature*, 510, 139-142

Paustian K., Cole C.V., Sauerbeck D., Sampson N., 1998. CO_2 mitigation by agriculture: An overview. *Climatic Change*, 40 (1), 135-162.

Perfecto I., Vandermeer J.H., Wright A.L., 2009. *Nature's Matrix: Linking agriculture, conservation and food sovereignty*, Earthscan, London, United Kingdom, 242 p.

Roudier P., 2012. Climat et agriculture en Afrique de l'Ouest : Quantification de l'impact du changement climatique sur les rendements et évaluation de l'utilité des prévisions saisonnières, PhD Thesis, EHESS, Paris, 189 p.

Roudier P., Sultan B., Quirion P., Berg A., 2011. The impact of future climate change on West African crop yields: What does the recent literature say? *Global Environmental Change*, 21, 1073-1083.

Saj S., Torquebiau E., Hainzelin E., Pagès J., Maraux F., 2017. The way forward: An agroecological perspective for Climate-Smart Agriculture. *Agriculture, Ecosystems and Environment*, 250, 20-24, https://doi.org/10.1016/j.agee.2017.09.003.

Sendzimir J., Reij C.P., Magnuszewski P., 2011. Rebuilding resilience in the Sahel: Regreening in the Maradi and Zinder regions of Niger. *Ecol Soc*, 16 (3), 1, http://dx.doi.org/10.5751/ES-04198-160301.

Soussana J.F., Lutfalla S., Ehrhardt F., Rosenstock T., Lamanna Ch., Havlík P., Richards M., Wollenberg E., Chotte J.L., Torquebiau E., Ciais Ph., Smith P., Lal R., 2018. Matching policy and science: Rationale for the '4 per 1000 - soils for food security and climate' initiative. *Soil & Tillage Research*, https://doi.org/10.1016/j.still.2017.12.002.

Tittonell P., 2015. Agroecology is climate-smart… (but the opposite is not necessarily true), extract from *Global Science Conference on Climate-Smart Agriculture*, Montpellier, March 2015, http://csa2015.cirad.fr/presentations (retrieved 29 December 2018).

Torquebiau E., 2015. Whither landscapes? Compiling requirements of the landscape approach. *In*: *Climate-smart landscapes: Multifunctionality in practice* (P. Minang *et al.*, eds), World Agroforestry Centre (ICRAF), Nairobi, Kenya, 21-36.

Torquebiau E., 2017. *Climate-smart agriculture* : Pour une agriculture climato-compatible. *Cahiers agricultures*, 26 (6), 66001.

Vayssières J., Assouma M.H., Lecomte Ph., Hiernaux P., Bourgoin J., Jankowski F., Corniaux C., Vigne M., Torquebiau E., Ickowicz A., 2017. Livestock at the heart of 'climate-smart' landscapes in West Africa. *In*: *Living Territories to Transform the World* (P. Caron, T. Wassenaar, G. Coppens d'Eeckenbrugge, V. Papazian, eds), Quæ, 111-117.

Wezel A., Soldat V., 2009. A quantitative and qualitative historical analysis of the scientific discipline of agroecology. *International Journal of Agricultural Sustainability*, 7, 3-18.